AIM Mission Responses to the Unexpected

Presented at

The PI-Team Masters Forum

By

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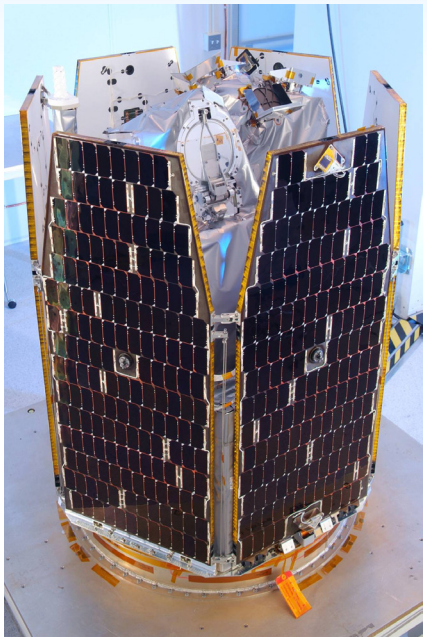
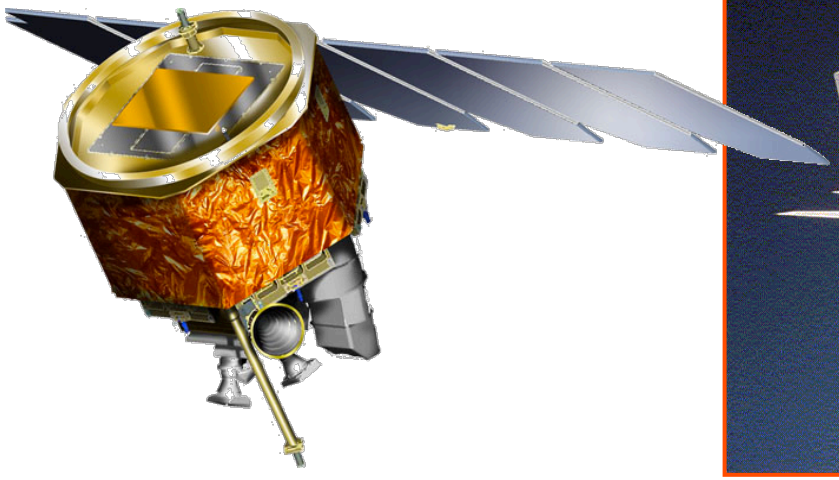
Aeronomy of Ice in the Mesosphere (AIM)

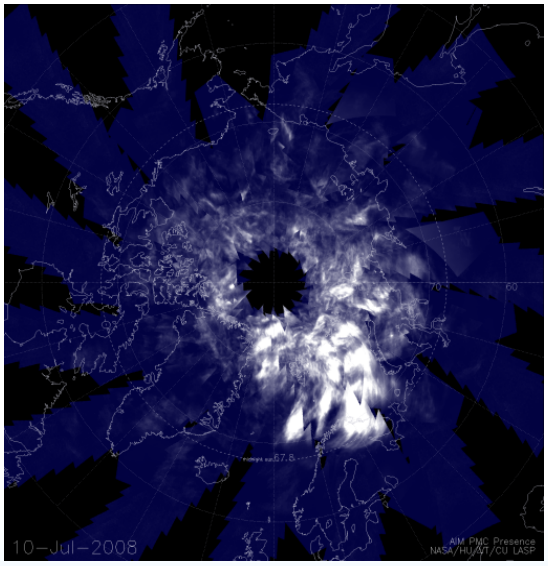
- **Three instruments**
  - **Solar Occultation (SOFIE)**
  - **Panoramic UV nadir imaging (CIPS)**
  - **In-situ dust detection (CDE)**

Why do noctilucent clouds form and vary?

AIM was launched from VAFB by a Pegasus XL rocket







NH cloud on July 7, 2008

- Launched April 25, 2007 at 1:26:03 PDT
- Near perfect 600 km orbit
- Observatory is working well and excellent data are being returned
- New insights about NLCs have been developed after just two cloud seasons
- Mission approved to go through 2012

AIM Responses to the Unexpected

AIM Selection Debrief August 20, 2002

- Serious skepticism about cost and schedule
- Will not confirm unless mission is within cost cap
- Inadequate funded schedule reserve
- Other Concerns
  - Low mass margin
  - SOFIE instrument immaturity
  - RS300 spacecraft immaturity

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At this point, science and cost became of similar importance

Timeline of major AIM actions taken after August 2002 debrief

CSR	Change	Action Date (2003)	Risk Reduction
SOFIE mass 50kg	Streamlined design, better science	March 15	Mass
First build spacecraft	5th generation spacecraft	June 3	Cost, mass
Four science instruments	SHIMMER removed, science impact	June 6	Cost, mass, data volume
IPA	Removed	June 15	Cost, mass
New LV contract	Use existing contract	June 19	Cost
CDE new development	Use New Horizons SDC copy	July 25	Cost, schedule
Six CIPS cameras	Four cameras, small science impact	August 1	Cost, mass, data volume

Last major AIM action taken after August 2002 debrief and before confirmation

CSR	Change	Action Date	Risk Reduction
Use Pegasus HAPS to trim orbit	Remove HAPS	Feb 2004	-----
Total overall estimated resource savings		$ 10.7 M 61 kg	-----

AIM timeline of other major actions taken after August 2002 debrief

- Actively pursued alternate spacecraft bus starting in October 2002
- Pursued Minotaur launch vehicle from Nov 2002 to June 2003; potentially significant cost savings
- Replaced baseline gyros with more expensive but more reliable and more capable units in Oct 2003
- Dealt with changing launch loads from Nov 2004 to launch
- Replaced SOFIE steering mirror with a rigid mirror in July 2006
- Developed work around to overcome intermittent loss of command capability in orbit

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Changed spacecraft vendor in May 2003

Significant Risk Reduction: Medium to high risk missions unlikely to be confirmed – use heritage hardware where possible.

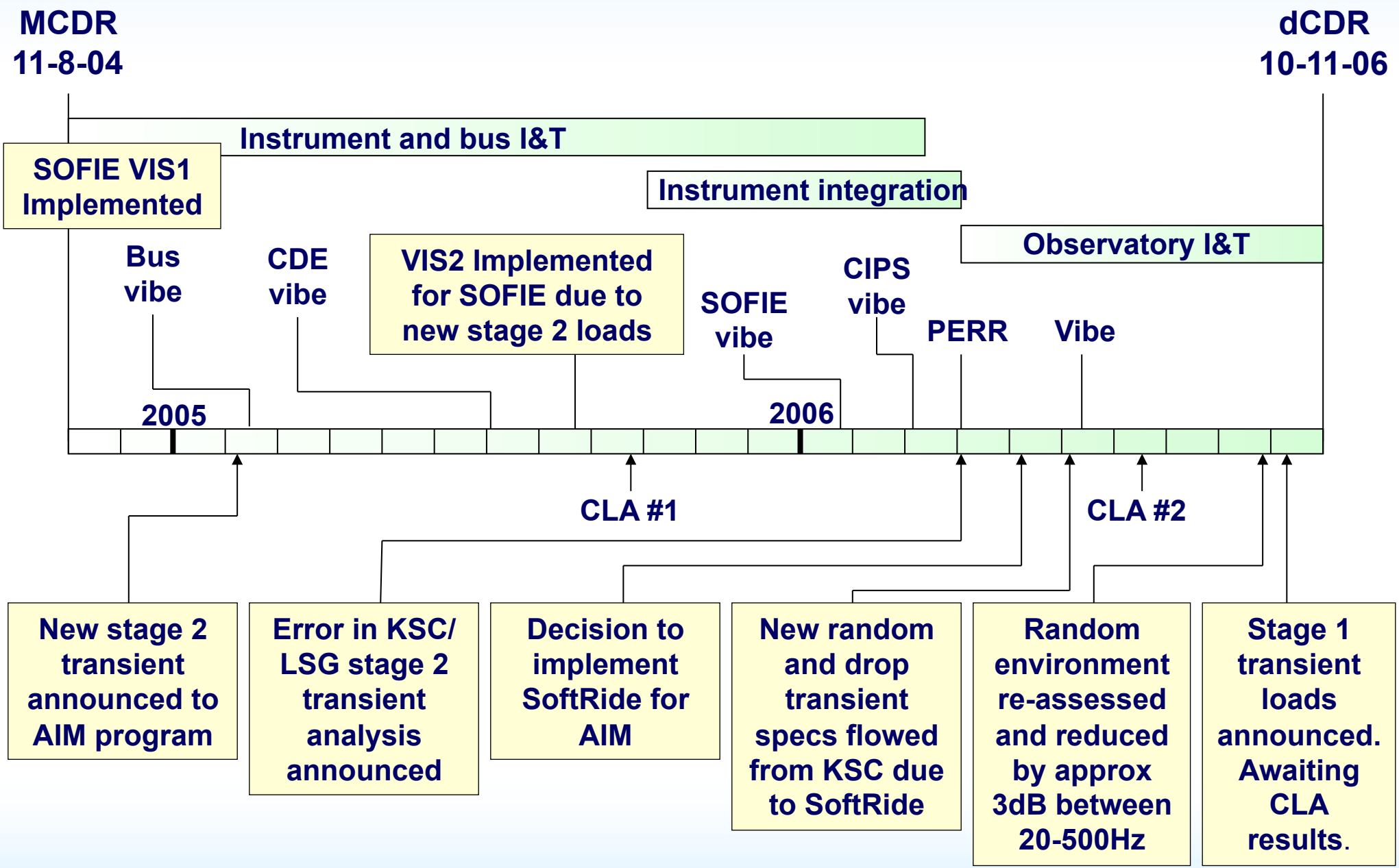
AIM S/C event history (Aug 2002 to June 2003)

- PI requested Ball VP to conduct a detailed RS300 bus cost review in Sept., 2002. Other cost reviews occurred later in the development.
- Started investigating spacecraft options in late Oct. 2002 and continued to work with Ball to seek resolution
- AIM funded OSC to do a detailed feasibility study for flying AIM alone on the VCL bus and LEOStar bus with positive results in May 2003
- Worked with NASA HQ from late Oct., 2002 until Mar. 2003 trying to secure the VCL bus
- Code Y would not commit to providing VCL bus to AIM mission
- RS300 cost review May 23, 2002
- RFP briefing from Orbital for a "SORCE like" spacecraft in June 2003

Dealt with changing Pegasus load environment from ~ Nov 2004 to launch

Be prepared to deal with evolving requirements

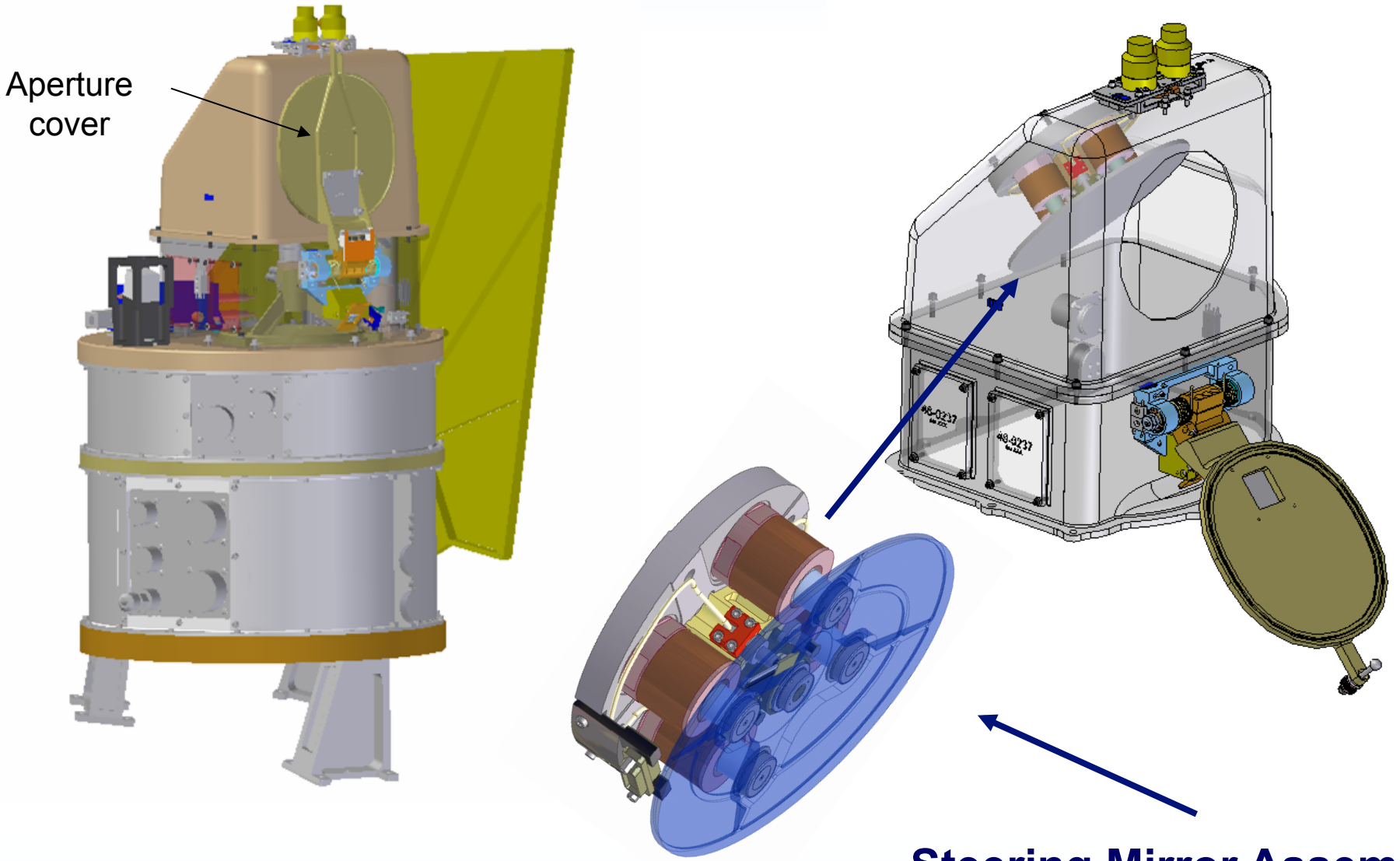
AIM Loads Environment History



Replaced SOFIE steering mirror with a rigid mirror in July 2006

Always be prepared with a carefully considered backup or descope plan in the event of unforeseen major issues

SOFIE instrument showing the Steering Mirror Assembly



An alternative to the SMA was in place as a backup approach

- Concern existed about the SMA actuator bonds to the back side of the mirror surface
- A "ghost" SMA was built by the vendor to allow more in-depth evaluation of the strength of the bond
- A rigid mirror backup approach with the spacecraft doing the SOFIE pointing was evaluated
- A rigid mirror was purchased, integrated and tested early in the SOFIE development in anticipation of problems
- Detailed science analyses were conducted and a rigid mirror approach was considered acceptable although not ideal

SOFIE Steering Mirror Assembly position sensor broke during observatory vibration

Four Options

- Repair of the flight Steering Mirror Assembly (SMA)
- Replacement of the flight SMA with a redesigned system
- Implementation of a caging mechanism for the SMA
- Replacement of the SMA with a Rigid Mirror Mount and rely on the spacecraft for pointing

At this point in time the scheduled Nov 2006 launch was 5 months away – not possible to make it

Launch actually occurred only 10 months after this anomaly!

Developed work around to overcome intermittent loss of command capability in orbit

Do everything within your power to create a cohesive and excited team. Show genuine appreciation for the team efforts.

AIM command uplink problem has been solved

- AIM started experiencing problems with lock on the uplink sub-carrier almost immediately after launch
- First extended outage of ~ 4 days occurred ~ 25 days after launch
- Intermittent bitlock is still present on the spacecraft today
- Root cause of the problem is unknown
- After a short time testing and trouble shooting, the PI asked the team to make the spacecraft and instruments as autonomous as possible as quick as possible
- Autonomous instrument operation achieved mostly by keying off periodic solar signals during the orbit
- Spacecraft commanding autonomy achieved by varying the amplitude of the uplink signal sent to AIM by TDRSS

The AIM team had to cope with an extremely large number of reviews

Be prepared to deal with evolving requirements from NASA

Reviews and Oversight

Reviews Beginning May 21, 2003

IIRT Plan 4/1/03

- ***Systems Requirements Review***
- ***MPDR / Confirmation Assessment Review***
- ***Confirmation Readiness Review***
- **Critical Design Review**
- **Pre-Environmental Review**
- **Pre-Shipment Review**
- **Operations Readiness Review**
- **Mission Readiness Review**
- **Launch Readiness Review**
- **Flight Readiness Review**

- **3 planned reviews grew to 29**

SRR		21-May
CIPS & CDE Cost Peer Review	WebEx	15-Jul
SOFIE Cost Peer Review	WebEx	16-Jul
WBS Cost Peer Review	WebEx,	17-Jul
SOFIE Δ Cost Peer Review	Webex	18-Jul
Orbital S/C Cost Peer Review	WebEx	21-Jul
Δ SRR	OSC	21-Jul
AIM Project Cost Peer Review	WebEx	6-Aug
CCSRR Peer Review	Webex	6-Aug
CCSRR	LASP	14-Aug
S/C Peer Reviews	Orbital	Oct
S/C PDR	Orbital	20-Oct
SOFIE Peer Reviews	SDL	Oct
SOFIE PDR	SDL	22-Oct
CIPS & CDE Peer Review	LASP	23-Oct
SOFIE DPDR Action Planning Meeting	SDL	28-Oct
CIPS/CDE PDR	LASP	6-Dec
Judson Detector Fact Finding	Judson	10-Dec
Bus Thermal Peer Review	Orbital	11-Dec
SOFIE Peer Reviews	SDL	13-Dec
SOFIE PDR	SDL	13-Jan
S/C Structure Peer Review	Orbital	20-Jan
Mission PDR	LASP	27-Jan
Confirmation Assessment Review	LASP	28-29 Jan
SOFIE Action Plan Assessments	SDL	Feb
Schedule Peer Reviews -- Staff and IIRT	Webex	4-Mar
Steering Mirror Peer Review	SSG	15-17-Mar
Confirmation Readiness Review	GSFC	19-Mar
AIM Confirmation Review	NASA HQ	28-Apr

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- **3 planned reviews grew to 29**
- **50+ Reviews from 5/03 SRR to 11/04 MCDR Including 3 SRRs and 2 SOFIE PDRs**

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EEE Parts program changes created problems late in the AIM development

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Mission Assurance Plan Changes

- Columbia Accident Investigation Board (CAIB) recommendations led to a change in Mission Assurance Plan Requirements
  - Came after long lead procurements on spacecraft
  - Involved significant discussion and review at highest levels of NASA just prior to launch
  - Held up observatory shipment to launch site for several days
- It is critical that EEE Parts requirements agreements be made in writing early to avoid ambiguities and problems late in the development

Key factors in the AIM implementation

- Recognize the wisdom and advice of the TMCO panel
- Place high importance on cost as well as science
- Have a very thorough knowledge of requirements and hold them sacrosanct
- Anticipate problems before they occur
- Plan backup approaches and work arounds
- Engage the entire AIM team in problem solving
- Involve the Executive Advisory Council in critical matters
- Make timely decisions
- Never lose sight of the mission science goal